USING PARTICIPATORY ERGONOMICS TO DESIGN AND EVALUATE HUMAN FACTORS TRAINING PROGRAMS IN AVIATION MAINTENANCE OPERATIONS ENVRIONMENTS

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Case studies where a participatory approach was used to design, implement and evaluate human factors training programs within in aviation maintenance operations environment is presented in this paper. A systematic evaluation model with five levels of training effectiveness measures was used to measure the effects of two human factors, maintenance resource management training programs. Positive gains from participatory ergonomics related to these human factors training programs are given.

INTRODUCTION

Participatory ergonomics is a macroergonomics approach that involves end users planning, developing and implementing workplace changes (Imada, 1991; Imada, Noro and Nagamachi, 1986; Hendrick, 1995). Participatory ergonomics includes end users designing useful work tools as well as developing and implementing ergonomics training programs. End users take an active role in the identification and analysis of ergonomic risk factors, workers' knowledge and skill deficits as well as the design of ergonomic solutions (e.g., job redesign, training, work organization). The participatory ergonomics process allows workers to get a better understanding of the ergonomic risk factors that can affect their behavior at work as well as their health and safety.

Participatory ergonomics is particularly useful at the planning stage, by involving workers in the identification and analysis of ergonomic problems. There are several approaches to participatory ergonomics, such as design decision groups, quality circles and worker-management committees. Some of the common characteristics of these various programs are worker involvement in developing and implementing ergonomic solutions, dissemination and exchange of ergonomics, health and safety information, pushing down in the organizational structure ergonomics expertise, and the cooperation between experts and non-experts (e.g., workers) and consideration and respect for workers' opinions.

Using a participatory ergonomics approach in designing and implementing workplace changes and training programs, creates a sense of individual ownership and commitment to supporting the training program and organizational goals. Being a member of a team that is developing and implementing an ergonomics training program is motivating, rewarding, and beneficial to both the individual and the organization. This involvement creates a willingness on part of the workers' to support the training program, and to engage in the required cultural change process. Further, working together on a cross-functional, interdisciplinary team provides a unique strength in designing and developing a training program (Robertson, 1988; Noro, 1991). If there is a lack of active worker participation in the training program, the worker's motivation for and understanding the material presented is low and their resistance to change is high (Luopajarvi, 1987).

This paper will present two case studies where a participatory ergonomics approach was used to design, develop and implement human factors training programs in aviation maintenance operations environments. These training programs were titled as "Maintenance Resource Management –(MRM-I and MRM-II)." The goals of these MRM training programs were to involve the end users in developing and implementing human factors concepts to reduce human errors, increase safety, and improve crew coordination and communication. These training goals were linked to the organizational goal of creating a cultural change in safety in each of the companies aviation maintenance operations. A description of the participatory ergonomics training program development and implementation process is provided, as well as the effects of the human factors training programs on workers attitudes, knowledge, behaviors and aviation maintenance operations performance.

HUMAN FACTORS TRAINING PROGRAM DEVELOPMENT

Designing and developing human factors training programs for aviation maintenance operations included working closely with industry representatives and subject matter experts over the course of a year. The overall model used to create, design and implement the training programs was based on Instructional Systems Design. This systems approach consists of five processes: 1) Analysis, 2) Design, 3) Development, 4) Implementation, and 5) Evaluation (Gagne, Briggs, & Wagner, 1988; Knirk & Gustafson, 1986; Goldstein, 1993). This process includes 1) setting goals and defining training objectives, 2) developing and implementing the training program, involving end users and/or subject matter experts, 3) measuring the effects of the training, and 4) providing feedback to the training developers.

Three types of analyses are conducted; organizational, task and person. These analyses determine the training needs and performance gaps, develop hierarchical task analyses, and create a learning hierarchy which identifies the existing skills, knowledge and ability levels of the trainees. In the design phase, the instructional curriculum, goals and objectives are defined. For the human factors training programs, we adopted a participatory design approach including the creation of a multi-disciplinary team of experts, end/users, in the areas of aviation maintenance, maintenance operations inspections, human factors, and FAA regulations. Also, on the training design team were representatives from management and union. Developing the training materials and media is the next phase and for these training programs we develop course lessons and group activities based on the companies own examples of maintenance operations and human factors issues. One of the strengths of these human factors training programs was the incorporation of these "in-house" examples into the training.

The next phase is implementing and delivering the training. Several members of the design team became training facilitators, who represent management and union perspectives. Each training workshop consisted of two co-facilitators. Training took place over several years, as over 2,000 maintenance personnel were scheduled to be trained. Evaluating the training program is the final phase of the instructional process involving assessing and modifying the training as prototypes of the workshop were being delivered. The second part in evaluating the training includes measuring the effectiveness of the training program on the trainees knowledge, behaviors and performance. There are several methods for evaluating training courses based on a five level framework (Kirk & Gustafson, 1986; Kirkpatrick, 1979; Gordon, 1994; Goldstein, 1993, Hannum & Hansen, 1992; Cannon-Bowers, et. al.). These levels of evaluation and the types of data that can be collected for each level provides a solid framework in evaluating training programs. These five levels include: 1) Baseline Assessment, prior to training; 2) Trainee reaction; 3) Learning; 4) Performance (behavioral changes); and 5) Organizational results. These levels were applied in evaluating the effectiveness of the two human factors training programs (MRM I and MRM II—Team Situation Awareness (SA)) designed for aviation maintenance operations environments.

HUMAN FACTORS TRAINING PROGRAMS EVALUATION

An evaluation results of these two (MRM-I; MRM-II) human factors training programs developed to improve team coordination, communication, and safety, and to reduce human error, demonstrated positive and significant results. (Robertson & Taylor, 1996; Taylor & Robertson, 1994; Robertson, Taylor, Stelly & Wagner, 1994). This evaluation provides a systematic approach to demonstrating the effectiveness of the training. Multiple measures and assessments of the maintenance personnel attitudes, self-perceptions of behaviors and maintenance performance were used spanning a 6 year period. This provided an unique opportunity to longitudinally measure and track the long term effects of the human factors training program. We also conducted analyses of the association between attitudes and organizational performance over time. Data were gathered through the questionnaires, on-site interviews and observations, trends of maintenance performance measures and attitude-performance analysis (Robertson & Endsley 1996, Endsley & Robertson, 1998, Robertson & Taylor, 1996; Taylor & Robertson, 1995).

Evaluation Results

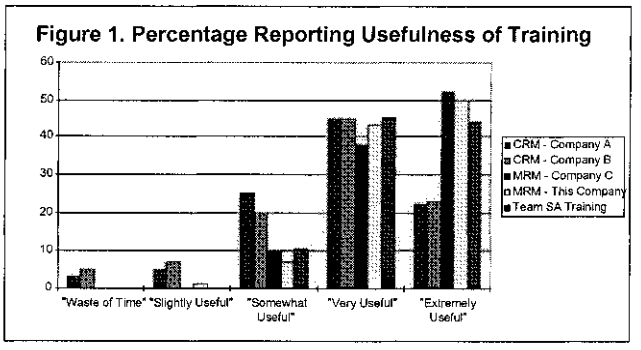
Overall results of the evaluation demonstrated a positive and significant effect of the human factors training on attitudes, behavior and organizational performance. The significant and positive improvements of the maintenance personnel attitudes reflected the expected and intended training effects on the participants' attitudes and their stability (consistency) over time. Results of each of the evaluation levels are:

Step I evaluation - baseline assessment. Two baseline measurements were taken before the MRM-I training intervention occurred to measure any changes in the trainees MRM attitudes and knowledge before the training commenced. With these two measurements

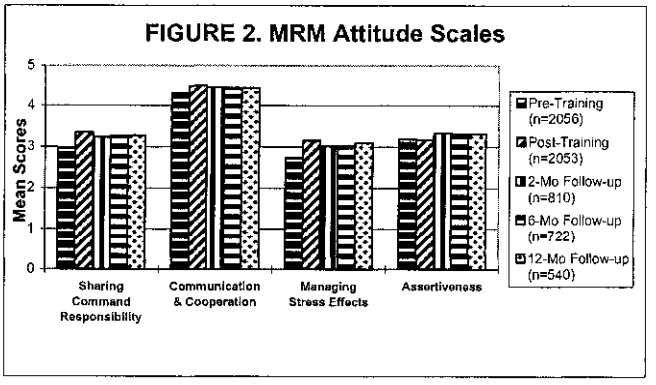
prior to the training a stronger quasi-experimental field research design is created. There were no significant changes found in the AMT's attitudes and behaviors as measured by the baseline and pre-training questionnaires.

Step II evaluation--reaction. This level of evaluation involved the participants' written reactions to the value and usefulness of the team training program as measured by the questionnaire. Several questions were developed to assess the trainees' reactions to the training course materials, objectives, organization, training climate, and instructor skills. This level of evaluation also served as a formative evaluation of training materials and delivery methods in the initial phases of the training program. Level II evaluation of MRM-I showed that the participants' immediate responses to training were positive, as over 90% rate the training as "very useful" or "extremely useful" including that over 96% felt that is was one of the best training courses they had attended. Other positive aspects of the course was the having a mix of participants in the class. This was beneficial because the managers were able to gain an appreciation of other managers' job functions, what their constraints and problems were and how the outputs of their jobs affect others in the work system.

Value and Usefulness. The post-training course questionnaire for MRM-II was used to measure the level of usefulness and perceived value of the course. Course participants scored each subsection of the course on a five-point scale which ranged from 1-waste of time to 5-extremely useful. On average, they rated each of the major topics as "very useful" (mean scores between 3.5 to 4.7). In addition to rating topics in the course, participants also answered several questions related to the course as a whole. The mean rating for the course overall was 4.3, corresponding to better than "very useful". A whopping 89% of the participants viewed the course as either "very useful" or "extremely useful, representing a high level of enthusiasm for the course. There were no low ratings of the course as a whole. Over 94% of the participants felt the course was either "very useful" or "extremely useful" for increasing aviation safety and teamwork effectiveness (mean rating of 4.4). Over 89% felt the course would be either very or extremely useful to others (mean rating of 4.3). Figure 1 presents the comparison of these MRM-human factors training programs for aviation maintenance operations versus similar human factors courses in aviation cock-pit resource management.



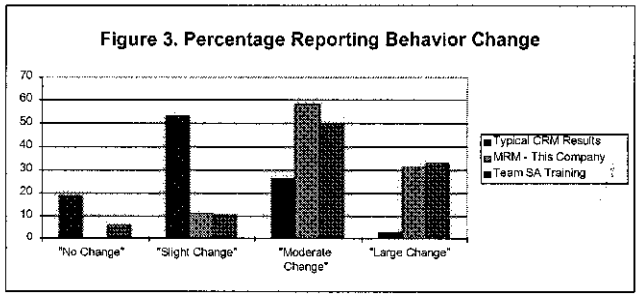
Step II evaluation--learning. For the MRM-I training, the knowledge gained and immediate changes in the participants' attitudes and the stability of these changes in time were measured by pre and post-training questionnaires. Changes in relevant attitudes measured immediately before and after training are significant with positive changes following training for three of the four attitude indices measured ("command responsibility," "communication and coordination," and "recognizing stressor effects"). The attitude measure of assertiveness rose significantly between the post measure and the 2 month follow-up survey. Follow-up results indicated that all four attitude scales remained high and stable over the two, six and twelve month surveys following training. (See Figure 2).

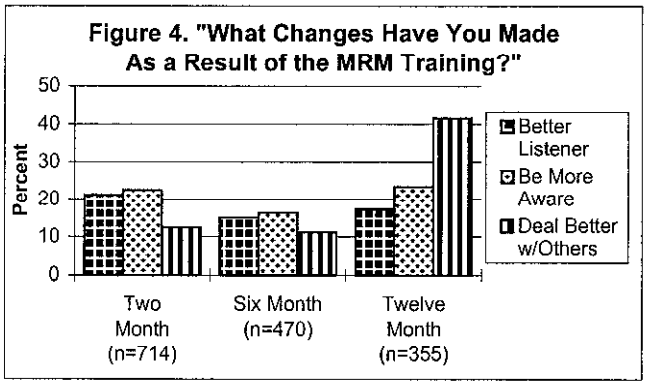


Step III: performance-behavior. Step III evaluation results of MRM I and II, derived and content coded from the open responses on the follow-up surveys, indicated how the trainees actually use the training on the job. For MRM-II training, when trainees were asked to what degree would the course affect their behavior on the job, 83% felt they would make a "moderate change" or a "large change" as shown in Figure 3.

As illustrated in Figure 4, the trainees' self-perception of their behavior on the job significantly shifted from "passive" responses (e.g., "be a better listener" and "being more aware of others") to improvement of more "active" responses, such as "having more daily meetings to solve problems,"

"gathering more opinions" and "getting more feedback from others." Field interviews and observations over a one year period were conducted to validate the contents of the self-reported behaviors.





Step IV: organizational results. Step IV evaluation examines trends in maintenance performance before and after the onset of the MRM-I team training program. One of these performance trends for occupational safety (lost time injuries-- rate of lost time injuries, per 1000 hours worked, for 55 work units). Overall, the injury rate remains at a low level for the year and a half after training was introduced.

Step V: evaluation: organizational performance and attitudes. For the MRM-I training, to correlate attitude changes with performance, the individual maintenance personnel data are combined into averages for the units to which they belong. The organizational performance measures included were aircraft safety (ground damage), personal safety (occupational injury), dependability based on departures within 5 minutes and on-time maintenance. Results from this analysis for the follow-up surveys shows a significant number of correlations between maintenance unit performance and attitudes.

CONCLUSIONS

As demonstrated in these case studies, applying a participatory ergonomics, macroergonomics approach results in positive and significant changes. Effects of human factors, maintenance resource management, training programs on maintenance personnel attitudes, behaviors, and performance were shown using a systematic, longitudinal, multiple measures approach. In using a participatory ergonomics approach, several positive gains occurred. These included gaining a higher level of acceptance of the training concepts due to the development of "in-house" examples, having a multidisciplinary team that represented different job functions and perspectives, having attained visible top management support and commitment, and linking the training objectives with the organizational goals and policies. With these elements in place, transferring the training concepts to the worksite as well as having them actively reinforced by supervisors and co-workers created the safety culture change within these maintenance operations environments to occur.

References

Endsley, M. R., & Robertson, M. M. (in press). Situation awareness in aircraft maintenance teams. *International Journal of Industrial Ergonomics.*

Gagne, R., Briggs, L., & Wagner, R. (1988). Principles of Instructional Design, 3rd edition. New York NY: Holt Rinehart and Winston, Inc.

Goldstein, I.L. (1993) *Training in Organizations.* (3rd ed.). Belmont, CA: Wadsworth.

Gordon, S., (1994). Systematic Training program design: Maximizing and minimizing liability. Englewood Cliffs, NJ: Prentice Hall.

Hannum, W., & Hansen, C. (1992). Instructional systems development in large organizations. Englewood Cliffs, NJ: Educational Technology Publications.

Kirkpatrick, D., 1979. Techniques for evaluating training programs. *Training and Development Journal,* 31, (11), 9-12.

Knirk, F.G., & Gustafson, K.L. (1986). Instructional technology: A systematic approach to education. New York: Holt, Rinehart and Winston, Inc.

Robertson, M.M. & Endsley, M.R. (1997). Creation of team situation awareness training for maintenance technicians. In Human Factors in Aviation Maintenance - Phase Seven, Volume 1 Progress Report (173-197). FAA: Office of Aviation Medicine, Washington, DC

Robertson, M. M., & Endsley, M. R. (1995). The role of crew resource management (CRM) in achieving situation awareness in aviation settings. In R. Fuller, N. Johnston, & N. McDonald (Eds.), *Human Factors in Aviation Operations* (pp. 281-286). Aldershot, England: Avebury Aviation, Ashgate Publishing Ltd.

Robertson, M.M., & Taylor, J.C. (1996). Team training in an aviation maintenance setting: A systematic Evaluation. In B. Hayward, A. Lowe, (Eds.), *Applied Aviation Psychology: Achievement, Change and Challenge.* (pp. 373-383). Avebury, Sydney Australia.

Robertson, M.M., Taylor, J.C., Stelly, J.W., & Wagner, R.H., 1994. Maintenance CRM training: assertiveness attitudes and maintenance performance in a matched sample. In Johnston, N.; McDonald, N. & Fuller, R. (eds.) *Aviation Psychology in Practice,* Aldershot, Hants: Avebury.